AD-A142 836 EXPERIMENTAL STUDIES OF A INVERTED CAVITY DYE LASER(U) 1/1
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W LIANZHI ET AL. 12 AUG 82 FTD-ID(RS)T-0803-82
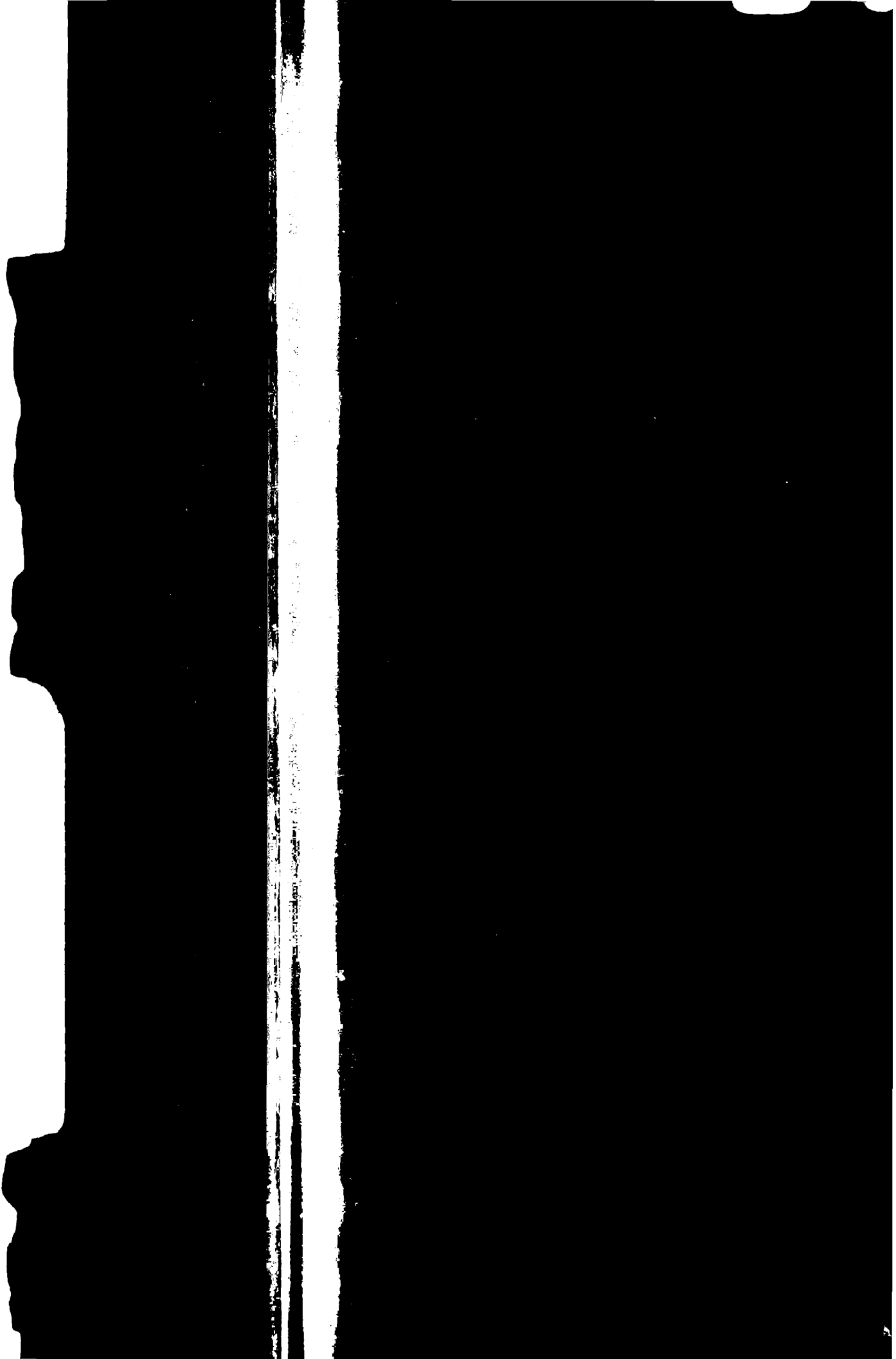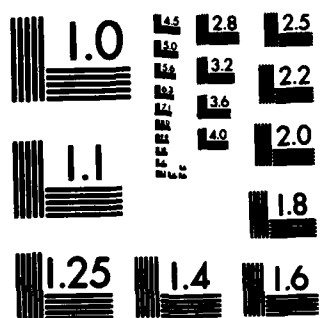UNCLASSIFIED F/G 20/5 NL

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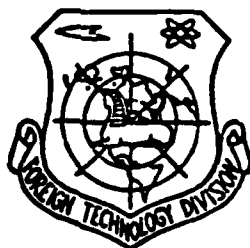# FOREIGN TECHNOLOGY DIVISION

EXPERIMENTAL STUDIES OF A INVERTED CAVITY DYE LASER

by

Wang Lianzhi, Yao Xinzo, Qiu Yuanwu

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EXPERIMENTAL STUDIES OF A INVERTED CAVITY DYE LASER

Wang Lianzhi   Yao Xinzo   Qiu Yuanwu

(Physics Institute, Academia Sinica)

The dye laser has been widely applied in many fields. The output /55(power of the ordinary pulsed optical pumping dye laser is of the order of several tens to several hundred watts, and its pulse width is of the order of microseconds. However, in many research areas, one would like to have dye laser output with high pulse power and narrow pulse width. Since the life time of the upper energy states is very short (e.g. the singlet upper energy level life time of Rhodamine 6G is 5.5×10^{-9} sec), it is very difficult to use the method of Q switch in the laser cavity to obtain a high powered pulse. On the other hand, an effective way to achieve high power and short pulse is the cavity inversion method. In this paper we introduced the experimental studies of the cavity inversion method used on the dye laser. The dye used is Rhodamine 6G; concentration is 10^{-4} mole. The inverted cavity pulse obtained has a wave length of 5900 Å and a pulse width of 11 millimicrosec. The output energy is 50 millijoules. The experimental results are basically in agreement with the theory. In this paper, we also analysed the key questions of getting cavity inversion laser output with high efficiency.

1. Basic Principles

The cavity inversion method has been used to obtain laser output with high efficiency and short pulse with results on several types of lasers. Preliminary investigation has also been carried out on the dye lasers.

The cavity inversion principle of the dye laser is shown in Figure 1. It is different from the ordinary laser resonance cavity. The two reflecting mirrors that form the resonance cavity are both total reflecting mirrors. Cavity inversion elements consisting of a
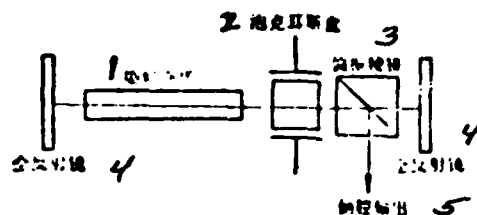
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Figure 1.

Key: 1--dye medium; 2-- Pockels cell; 3-- polarization prism;
4--total reflecting mirror; 5--inverted cavity output

Pockels cell and a polarizing prism are installed in the cavity.
Photons from the excited dye medium oscillate back and forth in the
totally reflecting cavity. The optical pumping process continuously
accumulates photons with hardly any laser output from the cavity.
In this process, the Pockels cell and the polarizing prism guarantee
that the resonance cavity is kept in a working state of high Q value.
When the value of photon density in the cavity reaches a maximum,
a half wave voltage is applied to the Pockels cell. As the polarized
light passes through it, the polarization surface rotates by 90°, the
photons are output in the direction of the perpendicular optical axis
by the polarizing prism until all the photons in the cavity are
exhausted. Hence, the output laser pulse width is

$$T = \frac{2L}{c} \, , \tag{1}$$

where L is the cavity length and c is the speed of light. Before
the potential on the Pockels cell is turned off, there will be no
laser output once the photons in the cavity are exhausted because
the resonance cavity is in a high output loss state. The dye is
a 4 energy level system. To analyse the cavity inversion effect,
R.G. Morton [1], et al used a set of much simplified rate equations
and obtained the approximate analytical expression for the photon
number density in the cavity as

$$\varepsilon = \frac{E^{D}}{E^{N}} = \frac{(2L/c)\Phi_{p}^{n}}{\tau_{i}\Phi_{p}^{\nu}}, \tag{2}$$

where E^{D}, E^{N} are the laser output energy (D represents the cavity
inversion method and N the ordinary method). $\Phi_{p}^{n}, \Phi_{p}^{\nu}$ are the maximum

photon number densities in the cavity, τ_l is the laser pulse width
for the ordinary method. Hence, other than suitably lengthening the
cavity length L, increasing the cavity photon number density ϕ_c^0 in
the cavity inversion method is a more important key in obtaining in-
verted cavity output of high efficiency. In the cavity inversion
dye laser, the factors affecting the photon number density in the
cavity are (1) the singlet state self-absorption of the dye medium,
(2) triplet state laser absorption of the dye medium, (3) loss due   /551
to the insertion of optical elements in the cavity such as the Pockels
cell, the polarizing prism, etc. With the exception of loss factors
(1) and (2) which are inherent to loss in the dye medium, the key question
of improving the inverted cavity efficiency is to reduce as much as
possible the insertion loss of the laser. Reference [1] estimated
that when the insertion loss was 0.1 (i.e., the percentage loss for
photons to travel once back and forth in the cavity), the photon
number density in the cavity inversion method is dozens of times
larger than that in the ordinary method. Thus, by carefully con-
sidering the insertion loss, it is entirely possible to obtain
inverted cavity laser output with high efficiency.

2. Experimental Method and Results

In order to carry out the measurement of resonant fluorescence
spectrum in the plasma diagnostic technique (such as sputtering
impurity diagnosis) and to use a color center
laser as optical pumping laser light source, we have investigated the
cavity inversion laser with high power and short pulse. The experi-
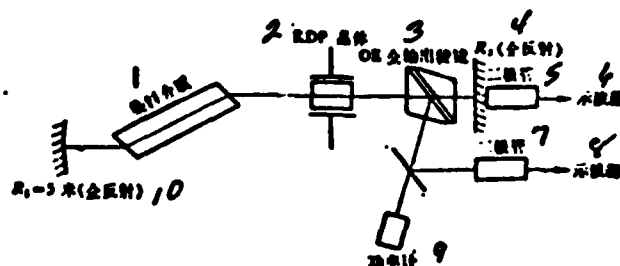mental set up is shown in Figure 2.

Figure 2. Experimental set-up.

Key: 1--dye medium; 2--KDP crystal; 3--OE total output prism;
4--R$_2$ (total reflecting); 5,7--diode; 6,8--oscilloscope; 9--power
meter; 10--R$_1$=5m (total reflecting).

To improve high power laser output, it is very necessary to use short pulsed optical pumping light sources. The optical source we have chosen is a co-axial cylindrical lamp. The co-axial lamp tube consists of 2 quartz tubes. Ø of the inner tube are 15 and 13 mm, Ø of the outer tube are 19 and 17 mm. The tubes and the electrodes are co-axial in structure with a distance of 1 mm between the tubes. The discharge length is 35cm. The silvered focussing mirror is tubular with diameter 35 mm and length 300 mm. The concentration of Rhodamine 6G Ethyl alcohol dye solution is 10^{-4} mole. The 1 mm gap between the tubes is the discharge chamber filled with flowing pure Argon gas with pressure of 50-80 torr. Flowing distilled water passes between the focussing mirror and the outer tube to cool the co-axial tubes on one hand and to strengthen the ability of the co-axial lamp support on the other to receive strong current discharge without shattering. Since the dye container is long, both ends of the dye container are sealed into Brewster angle windows to prevent the production of self-oscillating laser light and to generate polarized laser light.

The resonance cavity of the laser is formed by 2 totally reflecting mirrors coated with multi-layers of dielectric films. The output side mirror is plane and the other is a concave spherical surface of radius of curvature 5m. This insures that along the long cavity, we have a structure of close semi-co-focussing. The Gauss light beam in the cavity is focussed in the vicinity of the polarizing prism to prevent the photons in the cavity leaking out. The Pockels cell is an electro-optic switch formed by KDP crystals. Under our conditions, the half wave potential is 9 K_v. The polarizing prism is a Glan OE total output prism with a hole diameter of 18 mm. This will reduce the insertion loss of the polarizing prism as much as possible. By experimental measurement, the transmissivity for the prism used is 88%.

The energy of the O light laser beam from the polarizing prism is recorded when it passes through a power meter. The pulse shape is displaye' on an OK-19 model oscilloscope with a high current diode. We also recorded the optical pulse signal inside the cavity

from the small amount of photons leaking out through mirror R_2. The entire discharge process block diagram is shown in Figure 3.
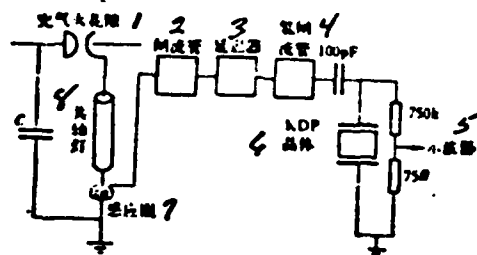

Figure 3. Synchronization block diagram of the discharge process.
Key: 1--gas-filled spark gap; 2--thyratron; 3--delayer; 4--hydrogen thyratron; 5--oscilloscope; 6--KDP crystal; 7--induction coil; 8--co-axial lamp.

We have obtained some results in our experiment. Figure 4 is the synchronous signal photographed from the Model OK-19 oscilloscope, indicating that the optical pulse signal in the cavity is well synchronized with the Pockels cell switch signal. Figure 5 gives the optical pulse signal in the resonance cavity. The pulse half width is about 0.9 μ sec. Figure 6 gives the inverted cavity laser output pulse signal obtained when the photon number density in the cavity reaches peak value together with the synchronous Pockels cell potential. The laser wave length is 5900 Å , output is 50 millijoules, pulse width,11 millimicrosecond. From the theoretical formula (1), calculated with cavity length L=180cm, we obtained T=12 milli-microsecond. The experimental result is basically in agreement with theoretical calculations. From this calculation, the output laser power is found to be 4 megawatt. In the experiment, we also used resonance cavity with R_2=20% reflectivity and measured the output signal of an /552 ordinary dye laser. Experiment indicates that the shape of the inverted cavity laser output is closely related to the correct switching time of the box.

Figure 6(a) and (c) show the inverted cavity output signal for leading
and delaying switching pulse respectively. When the switching pulse
precedes the maximal photon number density in the cavity, a definite
multiple-peak phenomenor appears.   When the switching pulse
lags behind the maximal photor number density in the cavity, the
inverted cavity laser pulse is significantly broadened. Only when
the switching pulse is synchronized with the maximal photon number
density in the cavity are we able to obtain a good output signal
as shown in Figure 6 'b).

Summarizing the above statements, we see that by applying the
cavity inversion method to dye lasers, it is possible to obtain
high power and short pulsed laser output. The pulse width is com-
pletely determined by the cavity length. It may vary from a few
milli-second to 100 milli-microsecond. The efficiency of the cavity
inversion laser output is basically determined by the insertion loss
of optical elements in the cavity. It is very important to construct
low loss Pockels cell and polarizing prism.

It must be specifically pointed out that the high voltage open
time of the Pockels cell must be much smaller than the inverted cavity
pulse width. When the high voltage open time (i.e., the use time)
is comparable to the inverted cavity pulse width, the cavity efficiency
will be severely affected. We have developed a triode gas-filled
co-axial spark gap composite switch as the high voltage pulse switch.
The rising, leading edge of its pulse may reach 5 milli-microsecond
or even as short as 1-2 milli-microsecond. This greatly increases
the inverted cavity efficiency. In addition, if the dye laser is
required to have tuned harmonic output, such harmonic tuning elements
as the diffraction grating, Faraday rotator, standardizer, etc. may
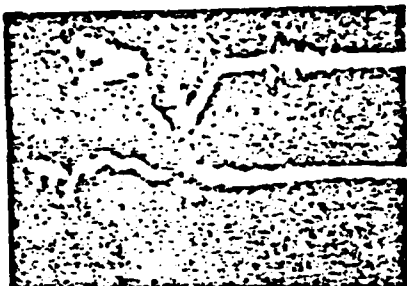be applied to the inverted cavity dye laser.

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Figure 4. A synchronous discharge signal. In this photograph the upper line is the optical pulse signal in the cavity of the inverted cavity dye laser; the lower line is the signal of the Pockels cell potential after voltage division.
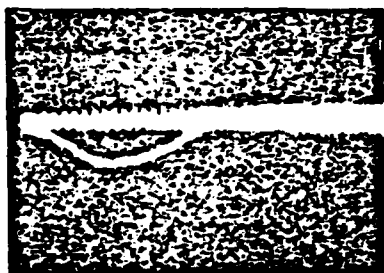

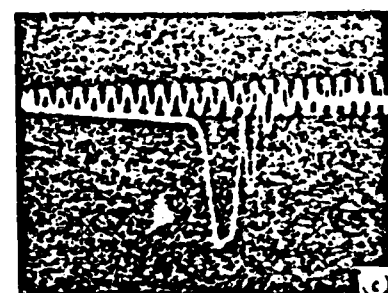Figure 5. Optical pulse signal in the resonance cavity
0.1 loss

Figure 6. a) Maximum photon number in the cavity before the switching pulse.
b) Maximum photon number in the cavity synchronous to the switching pulse.
c) Maximum photon number density in the cavity lagging behind the switching pulse.

Reference

[1] R.G. Morton et al., Appl. Opt., 17-20 (1978), 3268.

ORGANIZATION	MICROFICHE
A205 DMATC	1
A210 DMAAC	1
B344 DIA/RTS-2C	9
C043 USAMIIA	1
C500 TRADOC	1
C509 BALLISTIC RES LAB	1
C510 R&T LABS/AVRADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
C591 FSTC	4
C619 MIA REDSTONE	1
D008 NISC	1
E053 HQ USAF/INET	1
E403 AFSC/INA	1
E404 AEDC/DOF	1
E408 AFWL	1
E410 AD/IND	1
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